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ENGINEERING ASPECTS OF FREQUENCY USAGE  
IN INTERNATIONAL BROADCASTING

December, 1954

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This report deals with the utilization of radio frequencies for certain forms of international broadcasting. Of necessity consideration must be given to the complex laws of nature governing the transmission of radio signals from a radio transmitter to distant areas of reception as well as to other factors which determine whether or not reception conditions are adequate. The purpose of this foreword is to describe the factors or to define the terms used in simple non-technical language.

It is common practice to divide the radio spectrum into parts or sections with a name for each. For instance, frequencies lying between 30 and 300 kilocycles are called low frequencies, those between 300 and 3,000 kilocycles are called medium frequencies, those between 3,000 and 30,000 are called high frequencies, etc. This discussion will be concerned only with the high frequency (h.f.) portion of the spectrum lying between 3,000 and 30,000 kilocycles. Since a megacycle is 1,000 kilocycles, the h.f. portion of the spectrum may be referred to as the 3 to 30 megacycle band.

Only specific parts of the h.f. range are assigned to international broadcasting. Each portion is called an international broadcast band. There are nine h.f. international broadcast bands. Of these, the first six are of greatest interest in connection with the operations with which this report is concerned:

The 4000 kc. or 4 mc. band between 3950 and 4000 kc.  
The 6000 kc. or 6 mc. band between 5950 and 6200 kc.  
The 7000 kc. or 7 mc. band between 7100 and 7300 kc.  
The 9000 kc. or 9 mc. band between 9500 and 9775 kc.  
The 11000 kc. or 11 mc. band between 11700 and 11975 kc.  
The 15000 kc. or 15 mc. band between 15100 and 15450 kc.  
The 17000 kc. or 17 mc. band between 17700 and 17900 kc.  
The 21000 kc. or 21 mc. band between 21450 and 21750 kc.  
The 25000 kc. or 25 mc. band between 25600 and 26100 kc.

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A single radio broadcast signal occupies not one but a number of adjacent frequencies. The actual width of a radio channel is twice the highest audio frequency transmitted. Therefore, it is common practice to divide each band into channels. In domestic broadcasting, 10 kilocycles is allocated to each channel, the center frequency being used as the channel designator. Originally this was done on the theory that if audio frequencies up to 5 kc. were transmitted there would be good reproduction of both speech and music.

In international broadcasting, because of the over-crowded condition of the radio spectrum, there has been a tendency to divide the international broadcast bands into 5 kilocycle channels although it is recognized that a single transmission may occupy a channel substantially more than 5 kc. wide. This degradation is important because it means that whenever two transmissions on adjacent 5 kc. channels are directed towards the same geographic target area there is at least a reasonable probability that receiving sets cannot differentiate between them. Obviously, if two transmissions are directed at the same target on the same channel, there is an even greater likelihood of interference.

Arbitrarily, dividing up the h.f. international bands into 5 kc. channels provides the following:

In the 4 mc. band	10 channels
In the 6 mc. band	50 channels
In the 7 mc. band	40 channels
In the 9 mc. band	55 channels
In the 11 mc. band	55 channels
In the 15 mc. band	70 channels
In the 17 mc. band	40 channels
In the 21 mc. band	60 channels
In the 25 mc. band	<u>100</u> channels

Total 5 kc. channels      480

Admittedly, the division of these bands into 5 kc. channels is

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partly empirical. However, it is necessary to an evaluation of the extent to which duplicated use of the spectrum is possible. For reasons set forth later, this study is concerned primarily with the utilization of the 280 five kilocycle frequency broadcast channels which exist in the six international broadcast bands lying between 3,950 and 15,450 kcs.

A large number of countries have broadcast operations in the international broadcast bands. This report is concerned with international broadcast operations such as those of the Voice of America (VOA), Radio Free Europe (RFE), and the American Committee for Liberation from Bolshevism, Inc. (LIB), which are intended to penetrate the Iron Curtain. Each of these three organizations operates a plurality of broadcast transmitters and two of them operate from a plurality of transmitter locations. Each has as its objective the delivery of programs to a number of target areas.

Attention is first directed to one part of the systems problem, namely, the delivery of one program from one transmitter over a particular propagation path to one defined target area. With this limitation in mind, the first step is to set forth the important factors which determine whether or not a program can be received by a willing listener, that is, a listener who wants to receive it. Briefly, these factors are six in number, as follows:

1. The power output of the transmitter
2. The radiation characteristics of the transmitting antenna including its directivity
3. The radio frequency chosen for the transmitter
4. The radio propagation characteristics of the transmission medium between the transmitter location and the desired

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4. (continued)  
reception area at the time of broadcasting
5. The intensity of various types of interference signals present at the receiving location - In this discussion it will be assumed that the principal interference produced at receiving locations is from jammers. There is much evidence to support this conclusion
6. The availability at receiving locations in the target area of radio receiving sets which can be tuned to the frequency of transmission

The first two factors, namely, transmitter power and antenna characteristics, are under the control of the broadcasting group. The third factor, namely frequency used by the transmitter, is partly under the control of the broadcasting group because presumably it has available to it a number of frequencies scattered throughout the h.f. bands under discussion. The fourth factor, namely, the propagation characteristics of the transmission medium, is not under the control of the broadcaster. The fifth factor, namely, interference assumed to be primarily signals from jammer transmitters operated for the prevention of reception of the broadcasts, is not under the control of the broadcasting group.

The sixth factor, namely, receiving set availability, is not under the control of the broadcasting group. Yet, it influences the choice of usable frequencies. Certain groups operate on the assumption that listeners in the target areas of concern do not have receivers which will tune above the 15 megacycle band. At least one group assumes that listeners in its target areas do not have receivers tunable above the 11 megacycle band.

The fourth factor is all important. This is the propagation

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characteristics of the radio transmission medium path between the transmitter and the desired reception area on the frequency in use at the time of broadcasting. Any useful study and analysis of the effectiveness of radio frequency utilization for international broadcasting must turn the spotlight on the characteristics of the radio propagation medium and particularly upon the variation of these characteristics with time.

At any particular instant of time, for a particular propagation path between the transmitter and the receiver there is a radio frequency which marks at least approximately the upper limit above which transmission of signals is wholly unsatisfactory. This is called the maximum usable frequency or MUF. A simple explanation of the meaning of this term is as follows:

1. If the frequency of transmission from a radio transmitter is moved upward from the MUF for a particular path then the strength of the received signal will fall off very rapidly to a point where no signal will be received.
2. If the frequency of the transmitter is moved downward from the MUF then the strength of the received signal will also decrease but not nearly so rapidly as when the transmitting frequency is moved upward.

From the above the following conclusions may be drawn:

1. For a given power and antenna the strongest signals will be produced in the target area if the frequency chosen for the transmission is at or near the MUF for the transmission path involved. Also, for this and

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## 1. (Continued)

other reasons, under these conditions reception in the target area will be most difficult to jam.

2. The selection of the right radio frequency for a particular broadcast is a matter of prime importance having a far greater effect on the results obtained than moderate changes in transmitter power or in antenna efficiency and directivity.

To the propagation specialist, the treatment just given this subject may appear to be both naive and superficial. Nevertheless, it serves to emphasize the importance of the characteristics of the propagation medium in determining the effectiveness of broadcasting. The big question is how to determine what is the right frequency for a particular broadcasting time, that is, how determine for some future date and time just what will be the MUF?

Fortunately, propagation scientists while they cannot predict with high accuracy the MUF for a future date and time can, from studies of the ionosphere and historical data, make useful predictions. The definition of this predicted MUF is such that it may be expected that 50% of the time the actual MUF will be above the predicted value and 50% of the time the actual MUF will be below the predicted MUF.

To recapitulate, to reach a given target area at a given time from a particular transmitter location, the international broadcaster has control of only three factors, namely:

1. The transmitter power
2. Transmitting antenna characteristics including directivity

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3. A limited choice of frequency assignments in the high frequency international broadcast bands

The selection of frequency assignment is all important. This is particularly true if the effects of jamming are to be minimized. To guide him in this selection the international broadcaster has available a predicted MUF for the time he proposes to broadcast, plus the knowledge that the actual MUF, while it may be different from the predicted value, is not likely to be too far removed from it.

To more clearly delineate the problems involved in attempting to provide for the most efficient use of frequencies for international broadcasting, it is desirable to resort to the case method of treatment.

Case 1 - Assume an international broadcasting group has available to it one transmitter site for serving one target area. Assume, however, a rather wide choice of frequency assignments - Question - how should the frequency to be used at a particular time be selected? Obviously, the best results will be obtained if a frequency close to or perhaps a little below the predicted MUF is chosen. Also, to minimize the effects of jamming, with only one transmitter the probability that the program will be received can be increased by repeating it from time to time.

Case 2 - Assume an international broadcaster has available one transmitter site and for instance six transmitters which may be used simultaneously to reach a particular target area. Assume further that for the time in question the predicted MUF falls in the middle

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of the 9 mc. broadcast band and also that there is an unlimited choice of frequency assignments within the 6 international broadcast bands of primary interest. Question - would best results be obtained by (a) broadcasting on one frequency in each of the six bands? (b) broadcasting on a group of 6 frequencies all in the 9 mc. band? or (c) utilizing some intermediate form of frequency distribution between these two extremes?

Case 3 - Assume one site, a number of transmitters, a knowledge of the predicted MUF and the availability of a number of frequency assignments grouped around this predicted MUF. It is true that broadcasting the same program on two channels will increase the probability of good reception. The use of three channels may be expected to still further increase the chance of hitting the actual MUF. Question - when does the law of diminishing returns make it unprofitable to add channels and transmitters to the number directed to the same area?

In this foreword attention has been directed to the parameters involved in selecting high frequency assignments for delivering the best possible service to a single target area from a single transmitter site. Actually, the entities engaged in international broadcasting operate considerably more complex systems than this. They all have a number of target areas more or less accurately defined and most of them have a plurality of transmitter locations. The logical approach to

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the broad problem of providing the most efficient utilization of frequencies for this service is to break each system down into its parts and then, after treating each part separately, integrate the results for the whole.

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~~SECRET~~ENGINEERING ASPECTS OF FREQUENCY USAGE IN INTERNATIONAL BROADCASTINGI - PURPOSE OF THE REPORT

The purpose of this report is to review the manner in which frequencies are used for international broadcasting and to recommend improvements which might be made in frequency usage by the Voice of America (VOA), Radio Free Europe (RFE) and American Committee for Liberation from Bolshevism, Inc. (LIB). Accordingly, this report will be concerned with the following subjects:

- A. A review of the present selection, assignment and frequency usage by VOA, RFE and LIB
- B. An examination of frequency usage of other countries and how this usage affects the usage of VOA, RFE and LIB
- C. An examination of methods in use to determine technical effectiveness
- D. A consideration of factors important to the most efficient and effective use of frequencies for international broadcasting
- E. The determination of recommendations which in the opinion of the authors are in accordance with the following objective - "A determination of the overall means for obtaining the most efficient and successful utilization of all frequencies presently used or usable for international broadcasting"

This report will emphasize the significance of engineering considerations in the assignment of frequencies and will suggest an engineering approach to the selection of frequencies to be used for the transmission of a particular program or programs or conversely for the designation of programs which will be best received when a particular frequency or group of frequencies is used.

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~~SECRET~~II - GENERAL CONDITIONS OF STUDY

This report is concerned with the international broadcast effort directed towards penetrating the Iron Curtain. It will consider VOA, RFE and LIB as representative of those groups which are interested in penetrating the Iron Curtain and will use the operations of these groups as illustrative of this type of international broadcast effort. Emphasis will be given to the frequencies used by these groups in and to the general areas of Europe, Western Russia and the Near East wherein there is overlap in the target areas which are the interest of all three. Generally speaking, RFE is interested in the friendly satellite countries behind the Iron Curtain; whereas both VOA and LIB are interested in reaching all areas behind the Iron Curtain. VOA broadcasts to areas outside the Iron Curtain as well. This report is not concerned with differences in the nature of programs, only with the areas to which programs are directed.

From a frequency utilization viewpoint, and thinking specifically of the transmissions which originate in or are directed to Europe, Western Russia and the Near East, the engineering problems bearing upon the effective use of frequencies are similar for all three organizations. The same laws of propagation governing transmissions on various frequencies prevail for all three and the same hazards to reception are apparent. Generally speaking, the same frequency bands are available to all three groups. Each is interested in using for each program that combination of transmitting facilities and frequencies that will provide the best signal in the target area of interest. While there are practical considerations which enter into a determination of what frequencies to use for a particular program transmission, it is apparent that all three groups are cognizant of the basic technical factors which bear

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upon effective frequency utilization and have the means for calculating whether a frequency is appropriate for a particular program or not. Each makes use of monitoring information to determine whether a signal is received at designated locations and the nature of the signal.

The objective of this study is the determination of methods for improving the effectiveness and the efficiency of frequencies used for international broadcasting. International broadcasting takes place at low, medium and high frequencies and all assigned bands in the spectrum are congested. The selection of low and medium frequencies is relatively simple when compared with the selection of high frequencies. This report will therefore be concerned with the more complex problem of high frequency broadcasting and with the application of engineering methods to frequency assignments for the areas where the problem is most complex, namely, the European, Western Russian and Near Eastern areas.

The very nature of high frequency broadcasting, depending as it does on the vagaries of the ionosphere, makes the assignment and usage of high frequencies difficult under the best of conditions. Under present world conditions, wherein a cold war exists, this problem is complicated still further. In international broadcasting at the present time, radio transmission facilities are a weapon in a very real sense. Efforts to transmit information across the Iron Curtain are countered by efforts within the Iron Curtain to destroy reception of those signals. Whether or not the effort to pierce the Iron Curtain is successful depends upon whether the signals are strong enough at the point of desired reception to overcome the counter efforts from within. It must be realized that under jamming conditions, a signal which might otherwise be perfectly good and usable may actually become of little or no use to the desired audience.

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It is essential, therefore, that the broadcast effort be so planned that it make full use of all available resources which provide an advantage over those attempting to counter this effort.

Within the above general conditions of study, this report will describe in the following sections the way in which frequencies are presently being used by VOA, RFE and LIB, the principles of frequency selection and usage which are consistent with engineering considerations, and the relationship of frequency usage by the above-named groups to that of other countries of the world.

~~SECRET~~III - PRESENT USAGE BY VOA, RFE AND LIB

There is a wealth of material available with respect to the use of frequencies by VOA, RFE and LIB. All of these groups have been most helpful during the course of this study by making available such material and by being available for discussion of various questions which have arisen.

For purposes of orientation, Figure 1 has been prepared to show for a typical day in May, 1954 the usage of frequencies by VOA, RFE and LIB at certain arbitrary hours. It shows for various times the number and types of frequencies being used to broadcast program material in specified languages. Whereas Figure 1 is not complete, it is illustrative of the nature of the broadcast effort of VOA, RFE and LIB. It shows for example, the fact that RFE and LIB usage is fairly constant throughout the day whereas VOA builds up to its heaviest schedule from approximately 1600-2200 GMT. The same numbers of frequencies are used by RFE and LIB at all times whereas the number of frequencies used by VOA varies considerably for different periods of the day with the maximum number being used during the period from 1600 to 2200 GMT.

Attention is directed to two factors of significance in Figure 1, namely -

1. The number of frequencies used to broadcast a particular program, that is, a particular language, at a particular time, and
2. The wide spread in frequencies used to transmit a program from a particular transmitting location at a particular time.

A detailed study of 97 programs broadcast by VOA, RFE and LIB between

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## TABLE OF FREQUENCY USAGE - MAY, 1954

VOA										RFE										LIB									
TIME	PROGRAM	STATION	FREQUENCY							PROGRAM	STATION	FREQUENCY							PROGRAM	STATION	FREQUENCY								
			4	6	7	9	11	15	17			4	6	7	9	11	15	17			4	6	7	9	11	15	17		
1200	ALBAN- IAN	TAN				2	2	4	1	POLISH	GER. PORT.		1	1	1				RUSSIAN			2		2	1				
			CZECH	GER. PORT.		1			1	1	2								RUSSIAN						1				
			HUNGAR- IAN	GER. PORT.		2	1				1	2	1																
1600	LITH	TAN			1	3	3	4		POLISH	GER. PORT.		1	1	1				RUSSIAN			2	2	1					
		MUN	1	2	1	1	1	1			PORT.				1	2	2		GEORG.				1						
		BBC		1	1	2	1			CZECH	GER. PORT.		2			1	1	2											
		SAL			1	1					PORT.				1	1	2												
	E.COAST						3	1	HUNGAR- IAN	GER. PORT.		2	1			1	2	1											
	URDU or TAMIL SERV. PROG.	COLOM- BO					1																						
		E.COAST						2	4	2																			
2000	RUMAN- IAN	TAN			1		1	2		CZECH	GER. PORT.	1	1			1	1	1	RUSSIAN		1	1	2	1	1				
		MUN		1		1					PORT.					1	1	1											
		BBC		2						POLISH	GER. PORT.		1	1			1	2	2										
	GERMAN	SAL								HUNGAR- IAN	GER. PORT.		1				1	2	1										
		E.COAST								BUIGAR- IAN	GER. PORT.		1	1	1														
	CZECH	TAN				1	1	1																					
		MUN	1																										
		BBC																											
	ARABIC RUSSIAN AFRS MISC.*	SAL																											
		E.COAST																											
		COUR		1																									
		MUN		1																									
		E.COAST				2		2	1																				
		MUN					1																						
2400	LITH. ARMEN- IAN	TAN		2	2	2	1			HUNGAR- IAN	GER. PORT.	1	4	1		4	3		RUSSIAN		1	2	2	1					
										CZECH	GER.		1																
		COUR			1					POLISH			1		1														
0400	LATVIAN MISC.*	TAN		2	2	2	1			HUNGAR- IAN	GER. PORT.		2	1					RUSSIAN		1	2	2						
											PORT.			2	1								1						
		E.COAST	1		1	1				CZECH	GER. PORT.	1	1	1	2														
									POLISH	GER. PORT.		2	1																
												1	1	3	1														
0800	--	--	15130	TAN	-	NO				CZECH	GER. PORT.	1	1			2	1		RUSSIAN			2		2	2				
			FURTHER	INFORMATION						POLISH	GER. PORT.			2	1		2	2											
										HUNGAR- IAN	GER. PORT.			1	1		2	2	2										

\*Miscellaneous frequencies are those used but for which program assignment was not ascertained.

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the hours of 1600 and 2400 GMT shows the following distribution with respect to the number of frequencies used per program:

20% of the programs used 2 or less frequencies,  
50% of the programs used 5 or less frequencies,  
80% of the programs used 10 or less frequencies,  
95% of the programs used 15 or less frequencies,  
Two programs out of the 97 studied used more than 20  
frequencies; one using 26 frequencies to Lithuania,  
the other using 36 frequencies to Russia.

In the above tabulation the number of frequencies indicated for a particular program includes all frequencies used for that program whether one transmitter location or more than one location was used.

A study of the frequencies, transmitter characteristics and antenna characteristics used for particular programs by the various agencies shows that in each agency engineering principles of assignment are evident. It is pertinent, however, to note that where a multiplicity of facilities and frequencies is used for a single program, resort must sometimes be made to the use of transmitter, antenna and frequency combinations which are not optimum. For example, at each transmitter location there are only a limited number of antennas beamed in a particular direction and appropriate for use with a particular frequency band. If more than that number of frequencies are used at a particular time from that location or if some frequencies in other bands than the best bands are used merely because facilities appropriate for such frequencies are available, then less than the optimum use of facilities may result.

The principal limitations in the designation of frequencies for programs in international broadcasting are the number of frequencies

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available and the facilities appropriate for use with the available frequencies to serve the desired target areas. A further limitation is a feeling that there is a lack or sparcity of receivers in the target areas which will receive in the broadcast bands above the 15 megacycle band. VOA uses no frequencies above 17 megacycles for transmission to the target area and only a few assignments in the 17 megacycle band. RFE uses no frequencies above the 15 megacycle band. LIB uses no frequencies above the 11 megacycle band. Propagation studies indicate that frequencies in bands above the 15 megacycle band are most valuable at certain periods of time and that these higher frequencies will become even more valuable in the next few years as the sunspot number increases. It would appear desirable, therefore, that a re-examination be made of the reasons behind the decisions to limit the use of frequencies as indicated.

In this study specific attention has been given to the number of frequencies used for broadcasting one program and to the spread in frequencies used to broadcast the same program from a given transmitting site. It is evident that the number of frequencies for many programs is quite large and that the spread of frequencies is quite wide. Questions may be raised as to what spread of frequencies is necessary and how many frequencies should be used, and where they should fall in the spectrum. Similarly, a question may be raised as to whether or not the total frequency usage per program now in practice as well as the spread used are greater than necessary. These are difficult questions to answer but it appears that the answer to the latter question may be "Yes, at times." The following sections will discuss these subjects in more detail.

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IV - PRINCIPLES OF FREQUENCY SELECTION AND USAGE  
CONSISTENT WITH ENGINEERING CONSIDERATIONS

The present pattern of frequency usage by VOA, RFE and LIB reflects a significant amount of sound engineering consideration. The basic question for consideration in this report therefore, is whether, and to what extent the use of frequencies may be improved by giving increased emphasis to engineering considerations in the programming of frequency assignments. With the use of multiple frequencies having different propagation characteristics and with the use of multiple transmission locations each having different transmission paths to a particular target area, one question must be continually in mind if efficiency in frequency usage is to be realized and if the available frequencies are to be used most effectively. That question is: Are some or any of the frequencies which are assigned to a particular program of only marginal value and do they have less than marginal potential for being effective? The corollary question is: Are certain frequencies the ones which really count? It is the purpose of this report to delineate those factors which have an engineering significance in the planning of frequency usage so that a particular frequency assignment may be evaluated in the light of engineering considerations independently of other considerations.

If there were no jamming from behind the Iron Curtain it would be possible and highly effective to use but one or two frequencies to transmit one program to a particular area at a particular time. If it were possible to monitor the program in the reception area and a rapid means of communicating results of such monitoring were available, it would be possible to adjust frequency assignments so that within the limits of available frequencies the very best frequency would be used at

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all times.

In international broadcasting at the present time the use of multiple frequencies, that is more than two frequencies to a given target area for a particular program is dictated by two factors; (1) propagation vagaries of the transmission medium and (2) the presence of jamming. The presence of jamming requires that the frequency used at a given time provide the strongest signal possible if it is to be effective. It is this factor which makes use of a frequency as close to the maximum usable frequency (MUF) as possible at all times desirable even though some lower frequency would be satisfactory in the absence of jamming. Since propagation vagaries of the transmission medium make it difficult to know exactly what frequency will be closest to the MUF at a given time, only the relative magnitude of this frequency can be predicted with reasonable accuracy. It is necessary for this reason to select from available frequencies a group which is close to and if possible includes the predicted MUF in order to insure that at any particular time a frequency as close as possible to the MUF will be in use. The number of frequencies required and the spread in frequencies for a particular group, and the best transmitting facilities to be associated with these frequencies are important engineering determinations which must be made if the most efficient and most effective frequency usage is to result.

There is no place in this report for an exposition of the theory of high frequency propagation via the ionosphere nor is it necessary. All agencies of interest have competent personnel versed in the art of making the necessary calculations provided they have available the proper information. However, it is necessary to emphasize the effect on frequency planning caused by the varying characteristics of the

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propagation medium. It is this factor which is often neglected by those not too familiar with the mechanics of ionospheric propagation. It is important to realize that any prediction of future propagation conditions, while indispensable in frequency planning, is at best but an estimate which must be made on a probability basis and is subject to error. For example, when a prediction is made as to the maximum usable frequency (MUF) over a given path for a given time, the probability is equal that the actual MUF at the time of the broadcast will be above or below the predicted value. Thus, while the use of frequencies near the maximum usable frequency generally results in the strongest signals at the point of reception, the inability to predict such conditions with great accuracy requires the use of certain expedients.

One expedient is to select a frequency somewhat below the predicted maximum usable frequency thus increasing the probability that the ionosphere will support transmission over the path at the time of use. For example, where available a frequency 15% below the predicted MUF is often used in commercial practice. Another expedient is to use a number of frequencies grouped about the maximum usable frequency. Such usage may be from one location or more than one location, the latter being preferable. A third is to repeat the program a number of times thereby increasing the statistical probability of its being heard. Frequently a combination of the latter two methods is used in international broadcasting.

The MUF is important in international broadcasting because the existence of jamming places a premium on getting the best possible signal strength into the area to be covered. If frequency assignments can be made which provide for use of a frequency as close to the actual

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maximum usable frequency as possible at all times, two advantages will accrue:

1. The strongest signal will be provided at the desired point of reception.
2. The burden on the sky-wave jammer will be increased by reducing its flexibility of location. The jammer must be so located as to have an equally good path if it is to jam effectively with comparable power. At some times of the day the problem of locating a sky-wave jammer where it can be effective is quite difficult.

Analyses made in this study tend to indicate that the value of a frequency close to the maximum usable frequency is of such significance that transmitter power and antenna directivity for a particular path, at a particular time of day are of secondary importance if the wrong choice of frequency is made. With the right choice of frequency both of these factors become important in making the signal the best possible signal, but they are not a substitute for the right frequency. The importance of these considerations makes it desirable and worth-while to exert considerable engineering effort to insure the use of that group of frequencies which will be most effective in maintaining the use of a frequency as close as possible to the maximum usable frequency without at the same time spreading frequency usage to the point that relatively ineffective frequencies are used.

The use of prediction information is essential in international broadcasting since programing and frequency assignments must be

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planned in advance. An understanding of the nature and value of prediction information is therefore necessary to effective programing and frequency planning. In order to improve prediction information and evaluate future potential broadcast effectiveness, it is necessary to determine as accurately as possible on a continuing basis the value of the past broadcast effort and the effectiveness of past planning. VOA, RFE and LIB engage in rather extensive monitoring operations to obtain continuing information with respect to the effectiveness of their operations. Used properly, such information can be extremely valuable in refining prediction information and in determining potential effectiveness of the frequencies used. Until recently, the monitoring information of these groups had not been kept in a standard form nor was it readily available for analysis on a frequency by frequency basis. Steps to standardize monitoring reports and to use IBM methods for recording have been activated which should greatly facilitate such analysis in the future. The studies reported herein, while made without the benefit of the IBM procedures, substantiate the value to be derived from improved methods of gathering monitoring information and the need for a continuing study of information so gathered. The need for tabulating this information in a form specifically designed to facilitate a study of the effectiveness of frequencies on a frequency by frequency basis is also indicated. Caution, of course, must be exercised in interpreting any monitoring reports since they do not show local jamming conditions at other receiving locations in the target areas.

To evaluate the significance of frequency usage on a frequency by frequency basis a detailed analysis was made in this study of VOA monitoring conducted in Helsinki and in Belgrade during the first six

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months of 1954. Some study was also made of monitoring results obtained by VOA at Teheran and Taipei. This monitoring information was studied on a month by month basis for January, February, March, April, May and June. Tabulations were made with respect to each program period and for each transmitting location showing for each month the percentage of times monitored that each frequency used for a program was received satisfactorily or better at the monitoring location. Whereas for detailed evaluation, account should be taken in such an analysis of all of the characteristics of the transmission facilities used at a particular time on a particular frequency, the most important consideration in determining whether a program is heard, appears to be whether or not the frequency is a proper one - that is the best one - for the transmission path involved. In the tabulation of data, plots were therefore made of all transmissions received at a particular monitoring location even though in some cases the antenna beaming was not optimum for reception at that particular monitoring location and even though the power used may have been low. It developed that if the frequency band used were not the best, percentage reception of a program would be low irrespective of the antenna bearing and the power used. For frequencies falling in what seemed to be a best band some variation could be noticed with antenna beaming or with power but the variation would generally be relatively less than the variation when a frequency band far removed from the best band was used except in those cases where the beaming was completely off.

Figure 2 is representative of the results obtained from plotting VOA monitoring data. It shows information gathered at Helsinki for programs broadcast between 1730-1800 GMT. A, B, and C of Figure 2 show all programs monitored during this period - this includes programs in Latvian

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SUMMARY OF PROGRAMS RECEIVED  
SATISFACTORILY IN HELSINKI

ALL PROGRAMS (1730-1800)

ESTONIAN (1730-1745)

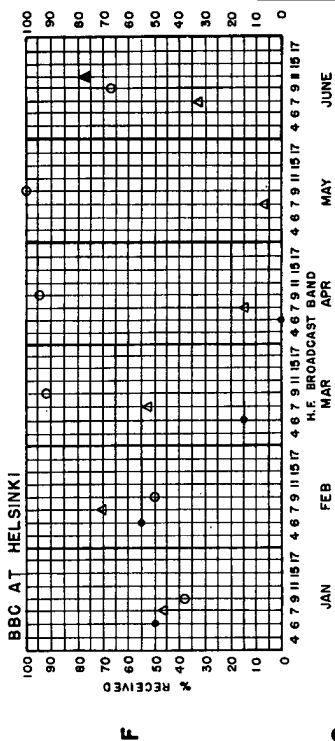
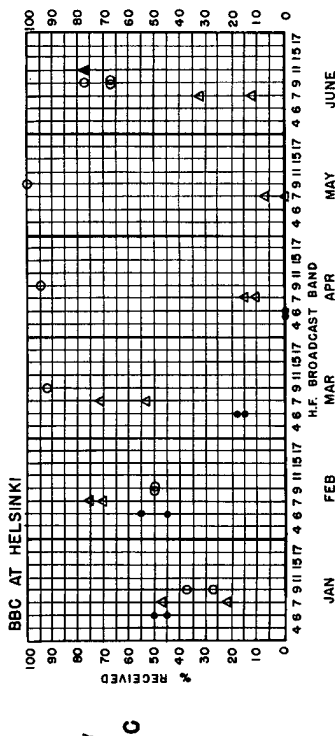
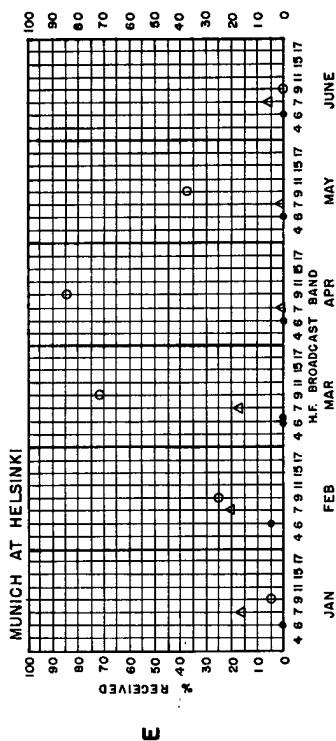
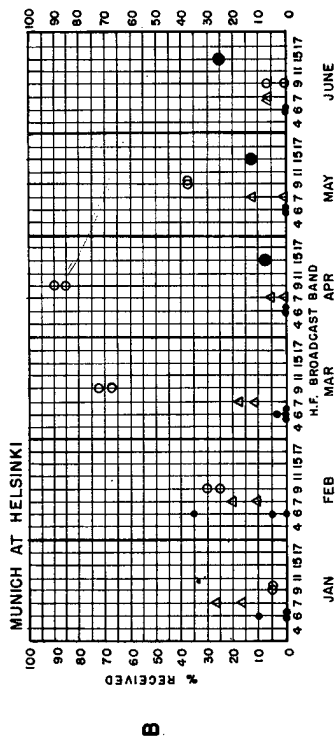
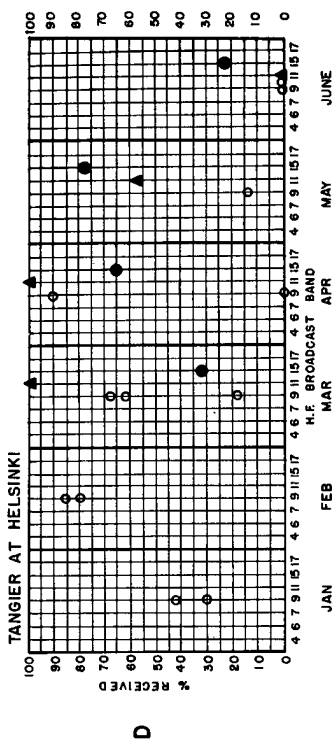
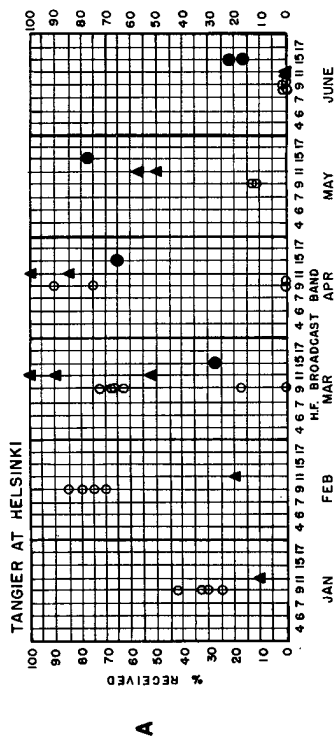


FIG. 2

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and Estonian; while D, E, and F show Estonian programs only. Each symbol in Figure 2 represents a particular 15-minute program on a particular frequency monitored several times during a month. The frequency band is indicated by the character of the symbol and by its location in the table. The percentage of times that the program on a particular frequency was received satisfactorily or better relative to the number of times monitored during the particular month is shown in percentage value as the ordinate.

It will be noted in Figure 2 that, for each month, programs in one band tend to group higher in percentage of times received satisfactorily than programs broadcast in other bands. The band which is best changes from month to month in a manner similar to the way in which the MUF changes. For example, in January frequencies in the 9 megacycle band seem to be best; in February the best band is still 9 megacycles; in March the best band is 11 megacycles; in April the best band is 11 megacycles; in May, 15 megacycles; and in June, 15 megacycles. None of the bands used indicate very good results in June.

Figure 3 shows a similar picture with respect to information gathered at Belgrade. In this case, the period shown is the period between 1845-1915 GMT. A, B, C, in this case show the results for all programs during this period and include Hungarian and Serb; and D, E, and F show the results for Hungarian only. The same type of picture as obtained for Helsinki is indicated in Figure 3 with respect to Belgrade.

It will be noted in B and E of Figure 3 that there are several broadcasts indicated on 4 and 6 megacycle frequencies which fall decidedly below other broadcasts on frequencies in these bands. The broadcasts

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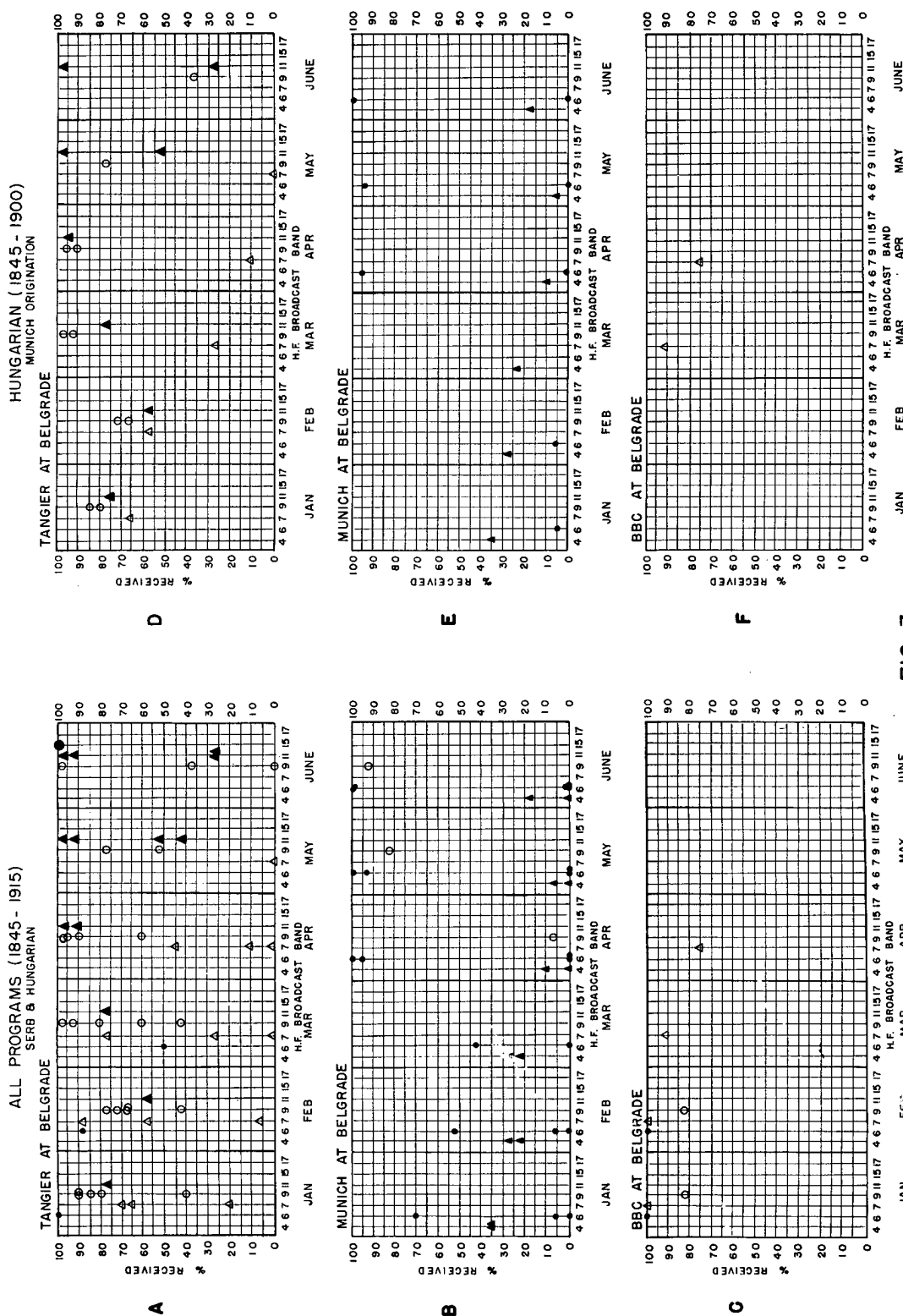
SUMMARY OF PROGRAMS RECEIVED  
SATISFACTORILY IN BELGRADE

FIG. 3

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falling low are those beamed 58/238° from Munich and are intended for reception in Tangier for relaying programs originating in Munich. This beaming is decidedly poor for reception in Belgrade.

For purposes of comparison with the actual MUF trend, Figure 4 has been prepared to show the MUF curves for each month from January to June for the path Tangier to Belgrade. An examination of these maximum usable frequencies and comparison with results obtained in Figure 3 show a close relationship between the best band as determined from monitoring and the band closest to the MUF which may be predicted from propagation curves.

Both Figures 2 and 3 show that there is a tendency for one band to be the best at a particular time and that the seasonal trend is as would be expected from prediction information. To analyze the relationship between monitoring information and MUF more closely, more detailed study of one set of data seemed warranted. Accordingly, all programs in Rumanian, Ukrainian, and Russian broadcast from Tangier and monitored in Belgrade during the period 1645-2000 GMT were selected as a sample. These broadcasts were chosen because these countries are generally in line with Belgrade and the transmitting point and it is known that all three broadcasts are jammed quite consistently. Figure 5 was then prepared to show the per cent of times monitored each month that each of these programs was graded "satisfactory" or better plotted against the frequency used, normalized to the predicted MUF for the time and path. In other words, a plot was made of the percentage of times a program was received in Belgrade satisfactorily or better as a function of the ratio  $\frac{\text{Frequency used}}{\text{MUF}}$ . While the data shown in Figure 5 are admittedly meager and the drawing of a curve is not justified, it should be noted that

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# PREDICTED MUF CURVES BELGRADE RECEIVING TANGIER 1954

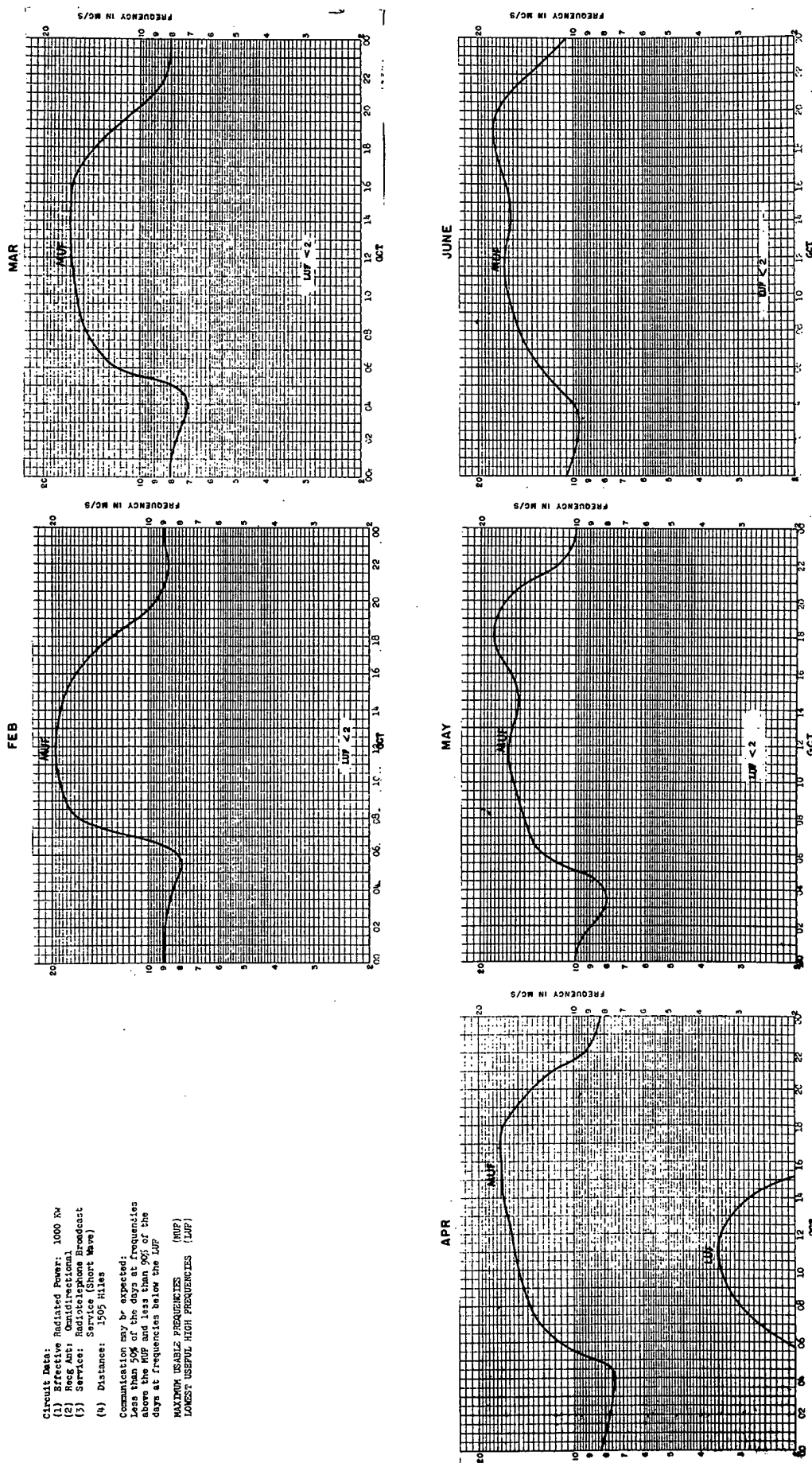


FIG. 4

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PERCENT OF PROGRAMS RECEIVED IN BELGRADE FROM  
TANGIER AS A FUNCTION OF RELATIONSHIP OF FREQUENCY  
USED TO MUF

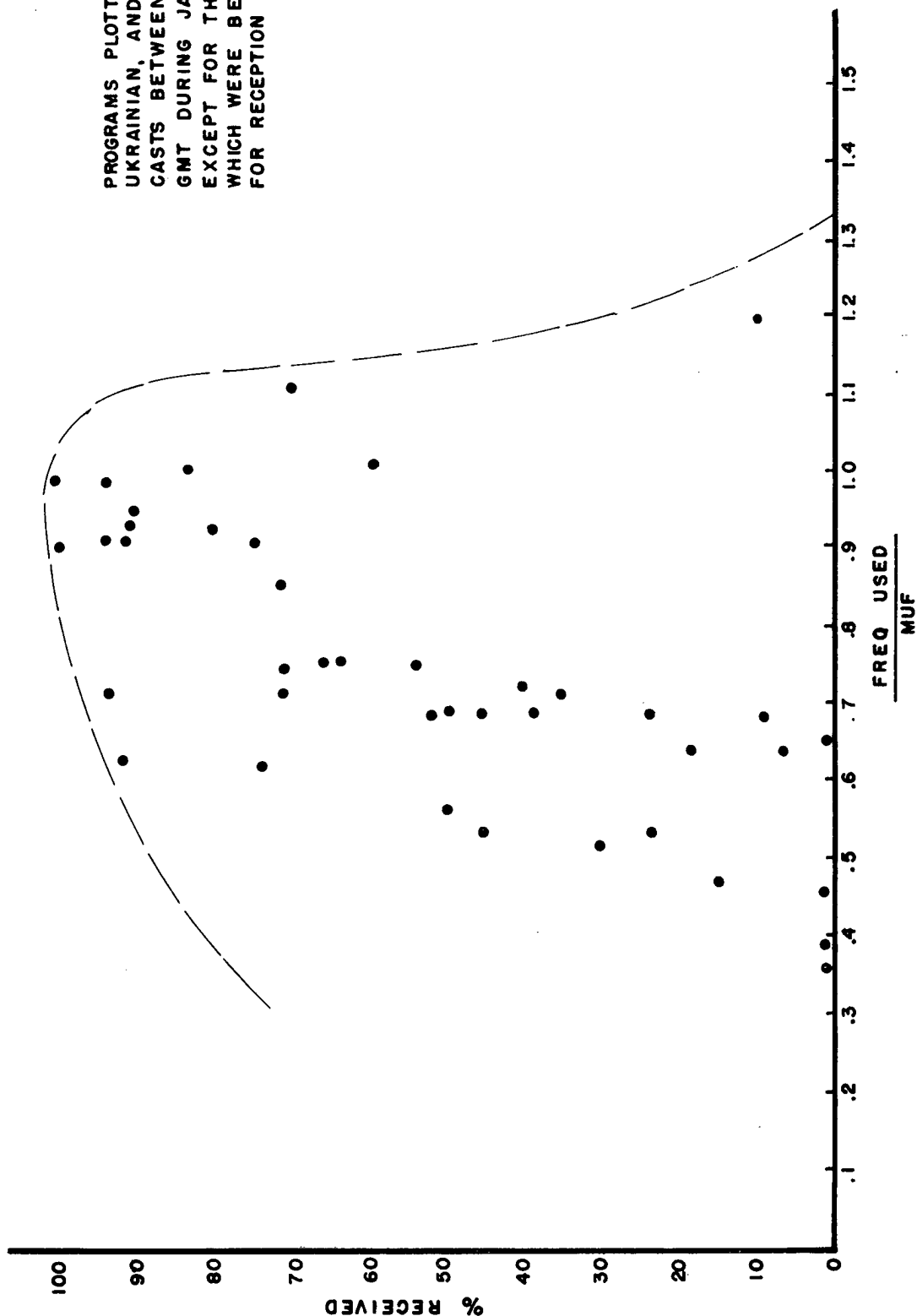


FIG. 5

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there is a concentration of high percentage points in the vicinity of 0.9 to 1.0. This tends to support the conclusion discussed earlier that frequencies close to the MUF have the best chance of getting through. To illustrate the general effect of jamming a dotted line has been drawn in Figure 5 to depict qualitatively the condition which might be expected if there were no jamming. Without jamming, the poorer frequencies, that is, those accounting for lower signal strengths because of the nature of the transmission path, would drop off in effectiveness at a lower rate than with jamming present. While this study has not developed this relationship definitely or quantitatively there is sufficient evidence of such a relationship to warrant further study to develop this in more definitive fashion. This study does indicate that the use of frequencies close to the MUF is highly important and that additional data gathered for the express purpose of determining quantitative results would be helpful. The results of this study confirm the fact that good monitoring data can usefully supplement prediction procedures to refine engineering information. It is clear that continued and increased effort in the use of monitoring results and the evaluation of monitoring information is essential to effective frequency planning. The practices recently placed into effect for improving the tabulation of monitoring information and for preparing such information on IBM cards are warranted and should prove highly valuable. Considerable time would have been saved in analyzing data in this study had information been available in the form that it is now being recorded.

While conclusions with respect to the quantitative determination of frequency grouping for multiple frequency broadcasts are not warranted, it is pertinent to take note of the way in which the

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international broadcast bands are distributed throughout the high frequency spectrum and the spread of frequency which is necessary when two or more bands are grouped for the same program. This is illustrated in Figure 6 where the relative locations of the various bands are shown along with a scale which may be used to determine the percentage spread in frequencies about a given frequency, for example, the MUF, when frequencies in various bands are used. For example, if the scale were cut out and used as a sliding scale and 1.0 placed corresponding to the 15 megacycle band, it would be noted that the ratio of the 11 megacycle band to the 15 megacycle band is .78 and the ratio of the 9 megacycle band to the 15 megacycle band is .63. The ratio of the 17 megacycle band to the 15 megacycle band is 1.2. The frequency spectrum shown in Figure 6 and the scale have been drawn on a logarithmic basis and may be used in slide rule form by copying or by cutting them out. Such a slide rule would be a useful device in frequency planning if some simple quantitative rules for grouping of frequencies could be developed.

Another example of monitoring analyses is shown in Figure 7. This contains a condensation of the results of monitoring conducted by RFE in Berlin and Vienna for the two-week period around March 1, 1954. The degree of shading is indicative of a rating given the particular frequency at various times of the day during the two-week period. Figure 7 shows in effect the diurnal variation in program rating for each particular frequency usage. It may be observed that the higher frequencies are the ones rated highest during the day and the lower frequencies rated best during the night for broadcasting from Lisbon. For broadcasts from Biblis the frequencies around 6 megacycles appear to be the best during the day. As a general observation it may be noted that whereas most

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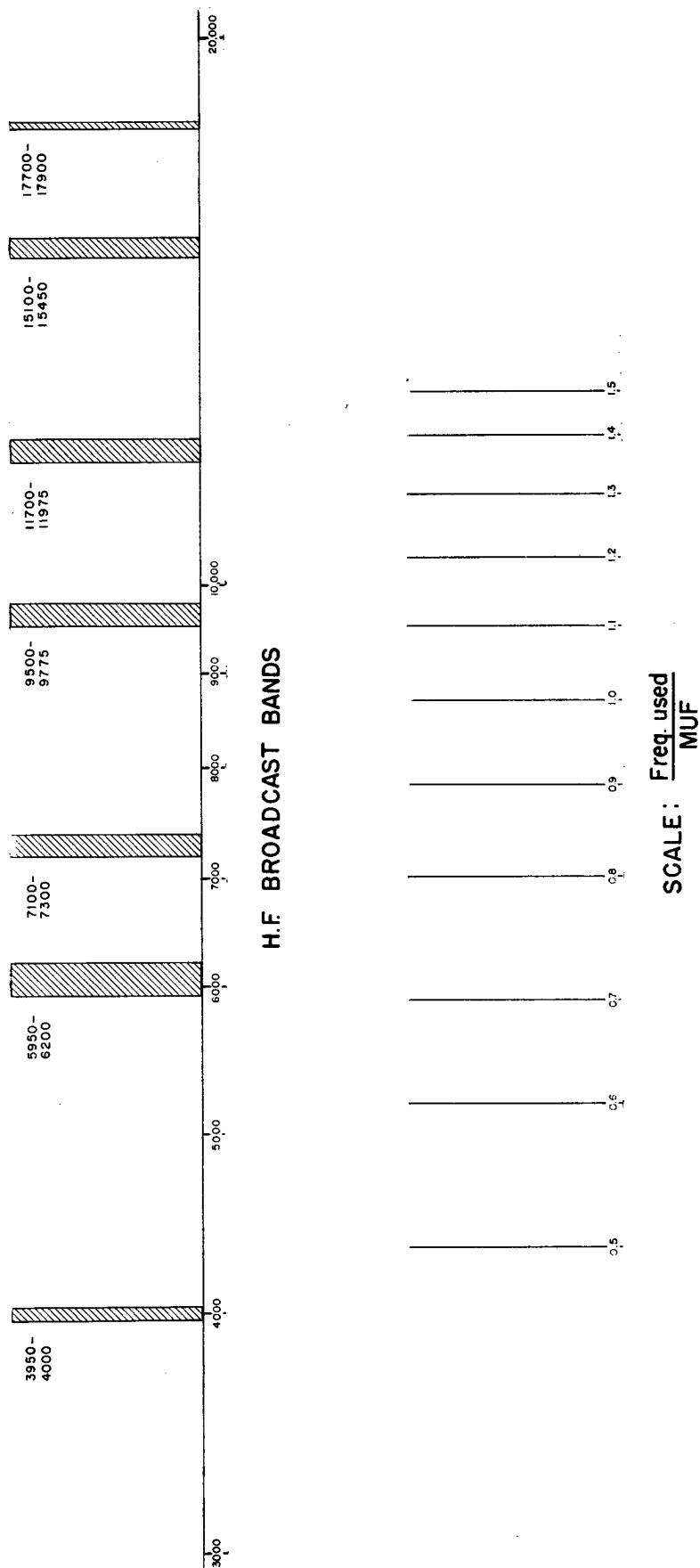


FIG. 6

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## RFE MONITORING SUMMARY

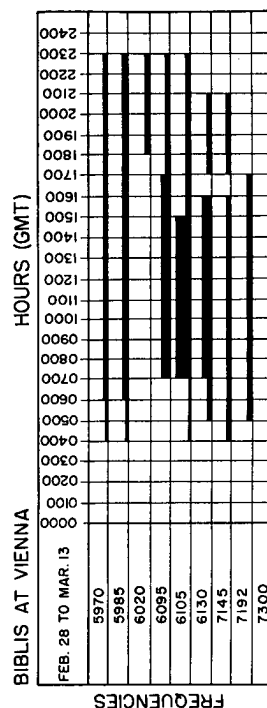
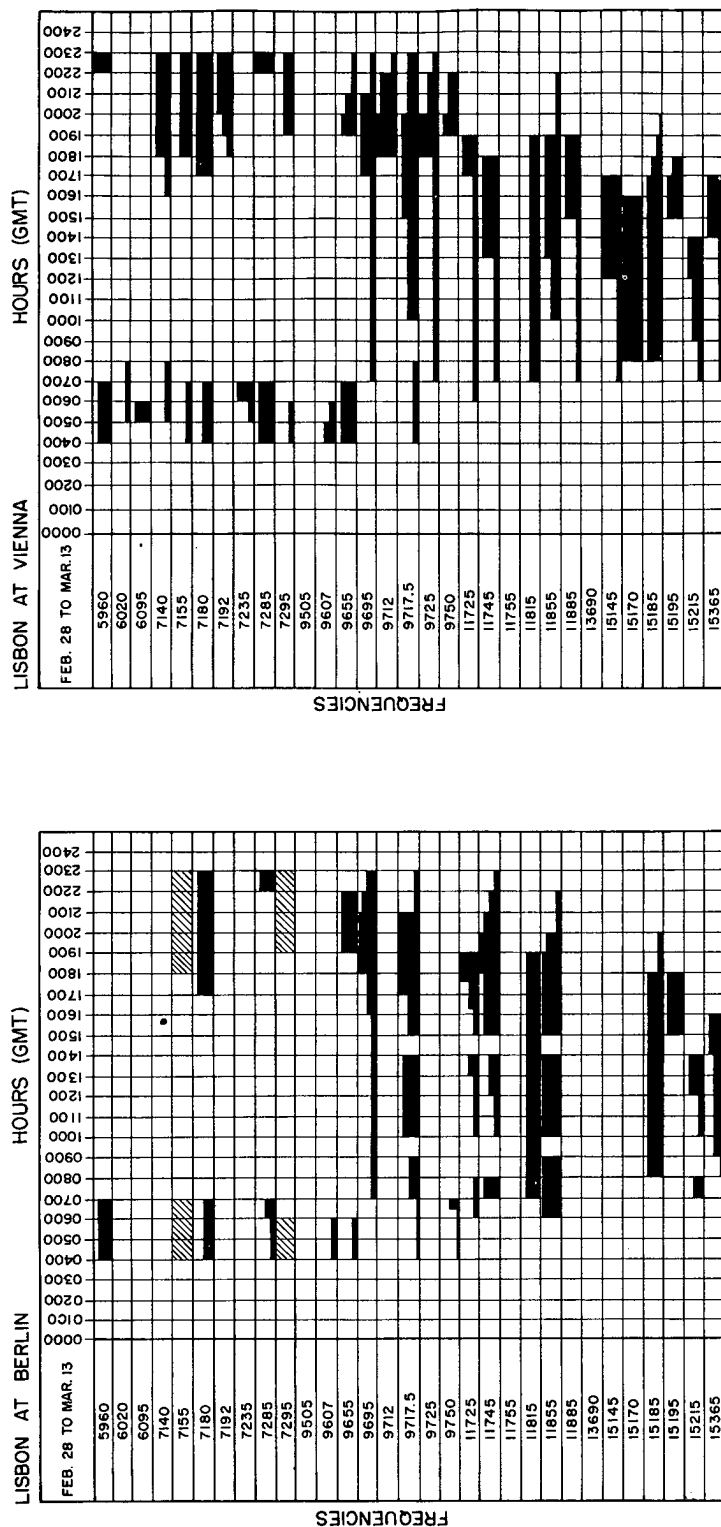


FIG. 7

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frequencies are used for a period of time before they reach the best rating some frequencies are shut off before they have dropped down in rating. It is the use of monitoring information which permits an agency to detect such conditions and adjust its frequency usage to take better advantage of the propagation medium.

A special problem with respect to VOA operations which has not been mentioned previously in this report is the transmission of program material from the United States and to a lesser extent from transmitting locations closer to the target areas. The principles of engineering usage are no different for such transmissions than from transmissions to the target area and the same type of analyses should be applied to them. However, it does appear that there is a need in assigning frequencies to differentiate between those frequencies used for relay purposes and those which are used for general broadcast coverage even though certain frequencies may be appropriate for both. Unless the target area for a frequency usage is well defined, it is difficult to assign the frequencies which will be optimum for providing effective and efficient use.

The use of frequencies for the transmission of programs from the United States to the transmitting locations close to the target areas satisfies a basic requirement for transmitting material for rebroadcast purposes. The use of frequencies in the United States for providing broadcast coverage in Europe is a supplement to the use of transmitters close to the target area and can be a valuable supplement when frequencies are appropriate for use from the states, that is when the frequencies are close to the MUF for the path from the United States to the target area and above for transmission paths closer to the target areas. Satisfactory reception in the target areas of such frequencies is particularly notice-

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able in monitoring reports at Belgrade.

It is worthy of mention that efforts are being made to predict "low-jamming" areas either by using available information as to the locations of jammers or by assuming that jammer locations are the optimum ones (from the point of view of the jammer). If methods for determining low-jamming areas are successful or if knowledge can be had that a particular language is not jammed whereas other languages are, then some increased flexibility may be realized with respect to frequency assignments over that which is practicable if the assumption is made that all frequencies are jammed and all areas are jammed. As developed in this report when jamming is encountered the usefulness of frequencies removed from the MUF decreases rapidly. If frequency assignments could be made with some knowledge of the jamming conditions to be encountered, advantage might be realized by placing priority for the use of frequencies closest to the MUF for those programs known to be jammed and giving lesser priority in the selection of frequencies to programs known to be jammed to a lesser degree or not at all.

Some comment is warranted as to the possible use of "back-scatter" techniques for determining the proper frequency to use for a particular area at a particular time. There are two different concepts of such use, one which may be looked upon as strategic, the other as tactical. Strategically, "back-scatter" measurements made on a continuing basis by scientifically trained personnel have the potential of adding to the available knowledge of the ionosphere over areas of interest. Thus, the results of such measurements when integrated with other data would serve to refine and improve propagation predictions. Measurements for this purpose should be under the cognizance of a scientific organization

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capable of analyzing the data, integrating them with other information and disseminating the results to all interested parties.

Considering the present state of the art, the need for operational experience with the use of "back-scatter" techniques and the difficulties associated with frequency adjustments within the international broadcast bands, the tactical or operational use of "back-scatter" techniques must be approached with caution. If "back-scatter" measurements are to be used for operational purposes it is highly important that methods be developed and personnel be trained to interpret such measurements and to use them properly. Careful planning and close control of frequency assignments and adjustments in frequency usage would be necessary in order to keep to a minimum the reservation of frequencies for possible use at a particular location or locations to provide for use of "back-scatter" information.

In brief, the results of this study show that considerable correlation exists between results of monitoring and prediction information and that effective frequency planning is therefore feasible and actually realized in practice. The problem is to improve this planning by continuing evaluation of information which can be obtained to improve engineering information, and to thereby narrow the margin of difference between actual results and predicted results. Full advantage should be taken of methods of achieving this result including the evaluation and use of such techniques as the "back-scatter" techniques wherever possibility for substantial improvement is indicated.

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V - RELATIONSHIP OF FREQUENCY USAGE BY VOA, RFE AND  
LIB TO THAT OF OTHER COUNTRIES OF THE WORLD

Obviously the use of high frequency broadcast bands by other countries limits the number of desirable frequencies available to VOA, RFE and LIB. Accordingly, a study has been made to determine how these limitations arise and the extent of possible conflicts which exist in high frequency broadcast bands.

Using information in files kept by the VOA as a basis, two charts have been prepared to illustrate the extent of frequency usage in the high frequency broadcast bands. Figure 8 shows use of 6 megacycle frequencies in the European areas. This includes transmissions which originate in the European areas and transmissions originating outside the European areas directed to that area. Figure 9 shows frequency usage in the 9 megacycle band throughout the world. In each of these figures the channeling is 5 kilocycles, and the time of use is indicated by a line within the particular channel being used. On each line there is indicated the country originating the transmission and the area for which the broadcast is intended. To emphasize the use of VOA, RFE and LIB, heavier lines have been drawn for usage by these groups with a particular code used to identify transmissions of the VOA originating on the East Coast of the United States or in Europe or Africa; a different code for VOA broadcasts from the West Coast of the United States or Asia, and a distinct code for RFE and for LIB. This coding is shown below. Also shown are the abbreviations used to indicate intended reception areas:

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Voice of America (VOA)

East Coast &amp; Europe Originations: \_\_\_\_\_

Voice of America (VOA)

West Coast Originations: \_\_\_\_\_

Radio Free Europe (RFE):

\_\_\_\_\_. . . . .

American Committee for Liberation

from Bolshevism, Inc. (LIB): \_\_\_\_\_

ABBREVIATIONS

AM - Americas  
 D - Domestic  
 E - Europe  
 FE - Far East  
 LA - Latin America  
 ME - Middle East  
 NA - North America  
 NE - Near East  
 O - Oceania  
 OV - Overseas (Several areas)  
 P - Pacific

There are no standards with respect to channeling in the international high frequency broadcast bands. However, by general practice there has been a tendency to assign channels on a 5 kilocycle separation basis even though transmissions on a particular channel may actually exceed this band width. There are relatively few assignments which do not fall on even 5 kilocycle frequencies. In Figures 8 and 9 such assignments are shown with an asterisk to show that the actual assignment is within 2 kilocycles of the actual frequency.

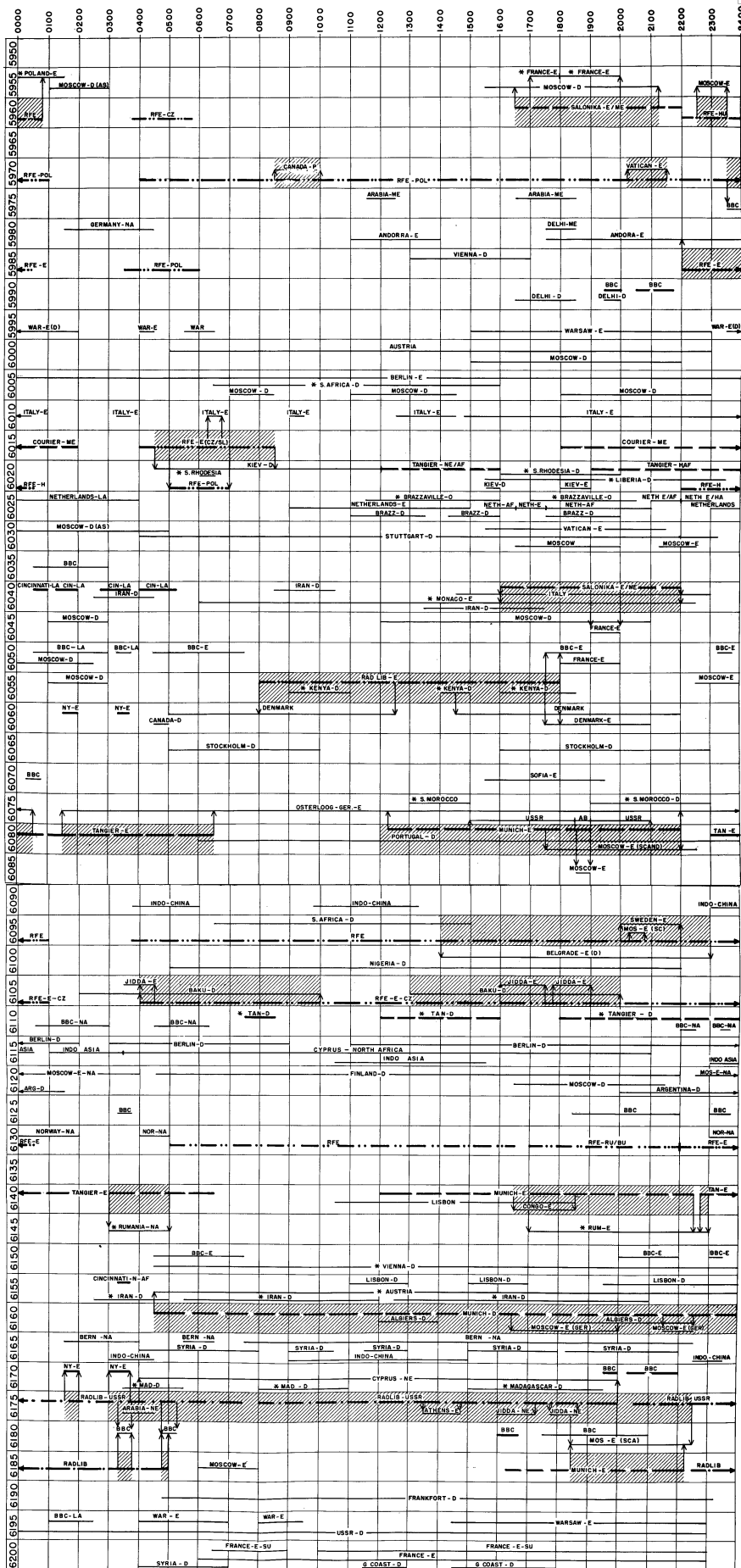
Whereas it is possible to assign high frequency channels within the general area of Europe using the same frequency or an adjacent frequency (5 kilocycles away) without conflict when the transmissions are directed to different reception areas, such assignments must be carefully engineered and may operate without conflict for only certain periods of

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FIG 8

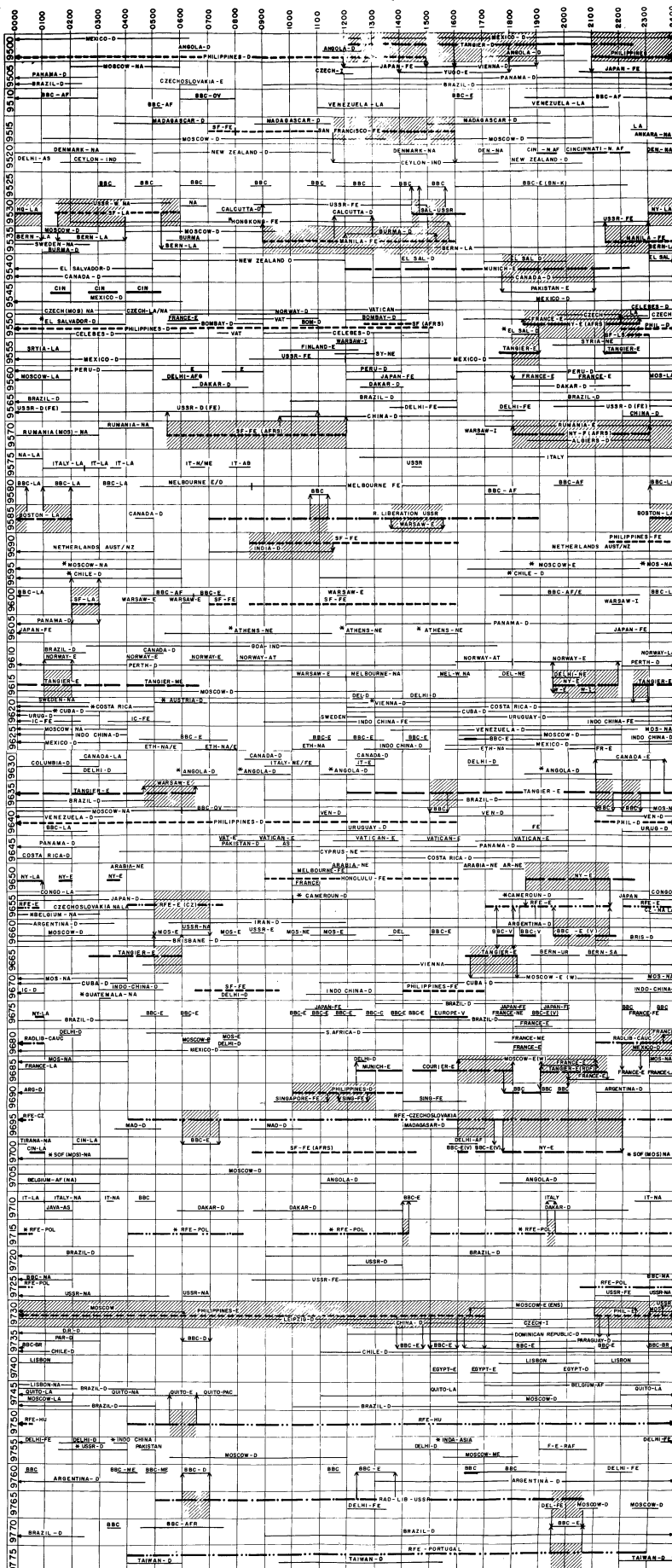


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FIG. 9



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the day, of the year, or for particular years. The problem with respect to 9 megacycle channels is more complicated than that with respect to 6 megacycle channels because the higher frequencies tend to propagate over a larger area. However, in general any multiple assignments of the same channel or adjacent channels for reception in the same general area must be looked upon as a possible conflict unless close coordination of usage is known to exist.

To show the effect of congestion in the high frequency broadcast bands, possible conflicts to VOA, RFE or LIB operations in Europe have been indicated in Figures 8 and 9 by shading wherever there is a transmission in or near the same general area on the same channel or adjacent channel to that used by one of these groups. Lines with arrows are drawn to indicate the operation causing the potential conflict. Although some of the potential conflicts shown are undoubtedly engineered so as not to cause interference, the existence of shading emphasizes the congestion already existing in the high frequency broadcast band.

The usages shown in Figures 8 and 9 are those for a particular day during the summer of 1954. These pictures of usage have changed in the short period of two months since the information was taken and several shifts in usage have occurred. The occasion for shifts is generally either to alleviate conflicts which have resulted in actual interference or to provide for new assignments. The world wide usage picture is not only a highly congested one - it is also a dynamic picture which is continuously changing.

The resolving of potential or possible conflicts is a very difficult task and one involving problems considerably more difficult than the engineering aspects themselves. However, resolution of such

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problems could be very advantageous to both parties if accomplished before actual interference results rather than handled after an interference situation actually occurs. The resolution of actual interference problems between friendly countries goes on all the time. It is important to realize and appreciate, however, that the treatment of conflicts on the basis of actual interference is only practicable where interference exists in a friendly country as the result of the operations of friendly countries. When the interference occurs behind the Iron Curtain, the detection of interference may be difficult or impossible even though it results from operation of two friendly countries outside the Iron Curtain. Such a situation requires handling on the basis of possible or potential conflict determined from engineering considerations rather than handling after interference actually occurs.

To illustrate the situation existing in the high frequency broadcast bands the following example may be used recognizing that the situation is over-stated and the solution over-simplified. Assume that two countries desire to broadcast to the same target area and that four frequencies are available. Assume further that the four frequencies are separated far enough apart in frequency that no adjacent channel interference would exist. If each country, without coordinating with the other uses all four frequencies then obviously interference will exist in the target area. Certainly it is not necessary to wait for interference to occur before being sure in such a case. On the other hand, if the two countries were to get together beforehand and each decide to use two different frequencies, then both countries could accomplish their broadcasts without conflict on any frequencies. Similar results are possible in the practical cases existing in international broadcasting if

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mechanism for coordination could be developed. Such coordination would probably be valuable even on a bilateral basis although a multi-lateral basis is to be preferred.

The purpose of Figures 8 and 9 is to show the need for frequency planning and also to illustrate the lack of flexibility of frequency usage within each band. Similar charts could be drawn for the other international broadcast bands. The usage in all bands, up to and including 15 megacycles would be similar. The usage in the 17 megacycle band and above is much less congested.

The problem of conflict between high frequency broadcast assignments is not unique with the international broadcasting service. This same problem exists with all services that use high frequencies.

Historically, frequency usage by countries has grown and old requirements have been supplemented with new requirements. It is very difficult to obtain on an international basis a realistic statement of a country's requirements. To solve this problem, the countries of the world agreed in Atlantic City in 1947 to establish the mechanics for engineering frequency assignments. This mechanism has been placed into operation and has met with considerable success - not without hard work and many difficulties - in many of the services. In services such as the aeronautical service, where requirements are tangible and frequency coordination an operational necessity, engineered assignments can be made and have been made. In the broadcast service, engineered assignments have not yet been realized and work directed towards establishing standards for operation is still in progress. As a practical matter, it seems that the only hope for making significant progress in the direction of having engineered assignments in international broadcasting

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lies in convincing all countries that such an engineered plan of usage would benefit all. A prerequisite to accomplishing this is an understanding in even a general way of the nature and consequences of congested usage such as is shown in Figures 8 and 9.

If charts such as those contained in Figures 8 and 9 could be used and supplemented with engineering considerations to show that a particular frequency usage by one country or by one group is providing only marginal effectiveness to it and is creating harmful interference to the use of the frequency by another country or group which has an effective use for it, then some progress in this direction might be realized. The ultimate solution to this problem will probably involve many steps and become involved with many associated difficulties - not the least of which is that of providing for subsequent use of a frequency at a period when propagation conditions warrant its use once the frequency has been released to another user because it is temporarily not needed.

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~~SECRET~~VI - CONCLUSIONS

The need for applying engineering considerations to programing and frequency planning has been emphasized throughout this report. Two directions of effort are indicated for improving the efficiency and effectiveness of the use of frequencies in international broadcasting.

These are:

- (1) The continuing study and evaluation of methods for assigning to programs only those frequencies which have a high potential effectiveness, and
- (2) Continuing efforts to reduce the occurrence of conflict between broadcast operations of the various groups and various countries resulting from multiple use of the same frequency or closely adjacent frequencies in areas where mutual interference may result.

Generally speaking, VOA, RFE and LIB are all making progress in improving predictions and in the evaluation of effectiveness through monitoring. There is a significant degree of coordination between these three groups both with respect to assignment of frequencies and in the gathering and evaluation of monitoring results. Notable in this connection is the relatively recent establishment of standard monitoring forms and the use of IBM procedures for listing results of monitoring and correlating these results with programing. This is a valuable undertaking and should definitely assist progress in the direction of improved application of engineering principles to programing and frequency assignments. Experience in this study indicates that considerable attention should be paid to the form in which monitoring information

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is kept and the way in which it is correlated to insure that an evaluation of effectiveness on a frequency by frequency basis as well as on the basis of overall systems efficiency may result.

Whereas the methods of programing by VOA, RFE and LIB are necessarily different the engineering principles basic to effective use of frequencies are the same for all. The specific application of engineering to programing and to frequency assignment in each group must necessarily take account of the nature of each particular operation. It is pertinent in this respect that the VOA habit of operation involves programing in 15-minute periods and a change in the target area, generally speaking at the end of a particular 15-minute period. Several programs may be broadcast simultaneously to different target areas involving the use of many transmitters, many frequencies and even many locations. The problem in such a case is a complex one and must be looked upon as a systems problem.

The RFE operation involves a relatively few target areas and broadcasts are made on a continuing basis throughout the day to each. Accordingly, RFE has less flexibility in the assignment of frequencies to programs and must concentrate on having the best frequencies for a relatively few programs which are broadcast over many hours on a continuing basis.

The problem which LIB faces is similar to that of the VOA in that an attempt is made to cover a vast area, or more specifically, many areas. At the present time, with only a few frequencies, the basic problem which this agency faces is to know how best to use those which it has to insure that the program associated with each is most appropriate for the area receiving the best coverage.

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The above comments are intended to indicate the particular viewpoint required in applying the following specific conclusions to the assignment of frequencies for VOA, RFE or LIB.

It is concluded that:

1. Effective frequency usage for international broadcasting in the h.f. spectrum requires engineering planning and coordination.
2. Engineering planning and coordination are evident in the operations of VOA, RFE and LIB.
3. There is room for improvement in frequency usage through the continued and improved use of more detailed and accurate data.
4. Were it not for the presence of jamming, a small number of frequencies from one transmitting location would be sufficient for broadcasting to one target area at any one time.
5. The presence of jamming places a premium on having a frequency near the "best" frequency at all times and reduces the value of frequencies which are well removed in the spectrum from the "best" frequency.
6. The bulk of frequency usage for international broadcasting must be planned in advance, therefore such usage must be based upon propagation predictions.
7. Actual conditions of the ionosphere at the times of broadcasting will differ from those predicted. The statistical probability of getting a signal through is improved by (1) multiple-frequency transmissions, (2) repetition of programs (3) a combination of (1) and (2).
8. Analysis of monitoring information to produce the information required can usefully supplement and serve to refine propagation predictions. Tabulation of monitoring information on IBM cards is a step in this direction.

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9. "Back-scatter" techniques properly interpreted and correlated with other propagation data offer the possibility of improving predictions over specific paths to the target areas. Operational use of such techniques should be approached with caution.
10. Selection of the proper frequencies and the number of frequencies necessary for a given program will be facilitated and improved by the information gathered through refined analysis of monitoring information and improved propagation knowledge.
11. World frequency usage complicates the entire picture. It certainly limits some degrees of freedom in frequency selection.
12. Where actual requirements for international broadcasting can be specified and coordination in frequency planning is possible, an engineering plan can serve to reduce conflicts between the operations of several countries (intentional interference excepted).

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~~SECRET~~**CONFIDENTIAL**VII - RECOMMENDATIONS

1. Establish a permanent group for the purpose of pursuing studies of all factors affecting frequency usage for international broadcasting of concern to the United States. Give such a group power to recommend changes to a parent body.
2. Make available to such a group refined propagation data, preferably based upon local information (near the pertinent paths) where such is deemed reliable.
3. Augment monitoring information by gathering it in a manner useful for frequency-usage planning and for evaluation of effectiveness on a frequency by frequency basis. Feed such information to the group recommended in 1.
4. Plan frequency usage to give the greatest practical probability of program delivery, at the same time releasing frequencies having a low probability at one location or for a particular program in order that they may be used at another location or for delivery of other programs.
5. Provide a mechanism whereby frequencies so released by one group may be available to other groups perhaps only for the period for which programs are prepared in advance.
6. Review considerations which limit the use of higher available broadcast frequencies than are now used.

Respectfully submitted,

December, 1954

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